Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems

Gary Blythe

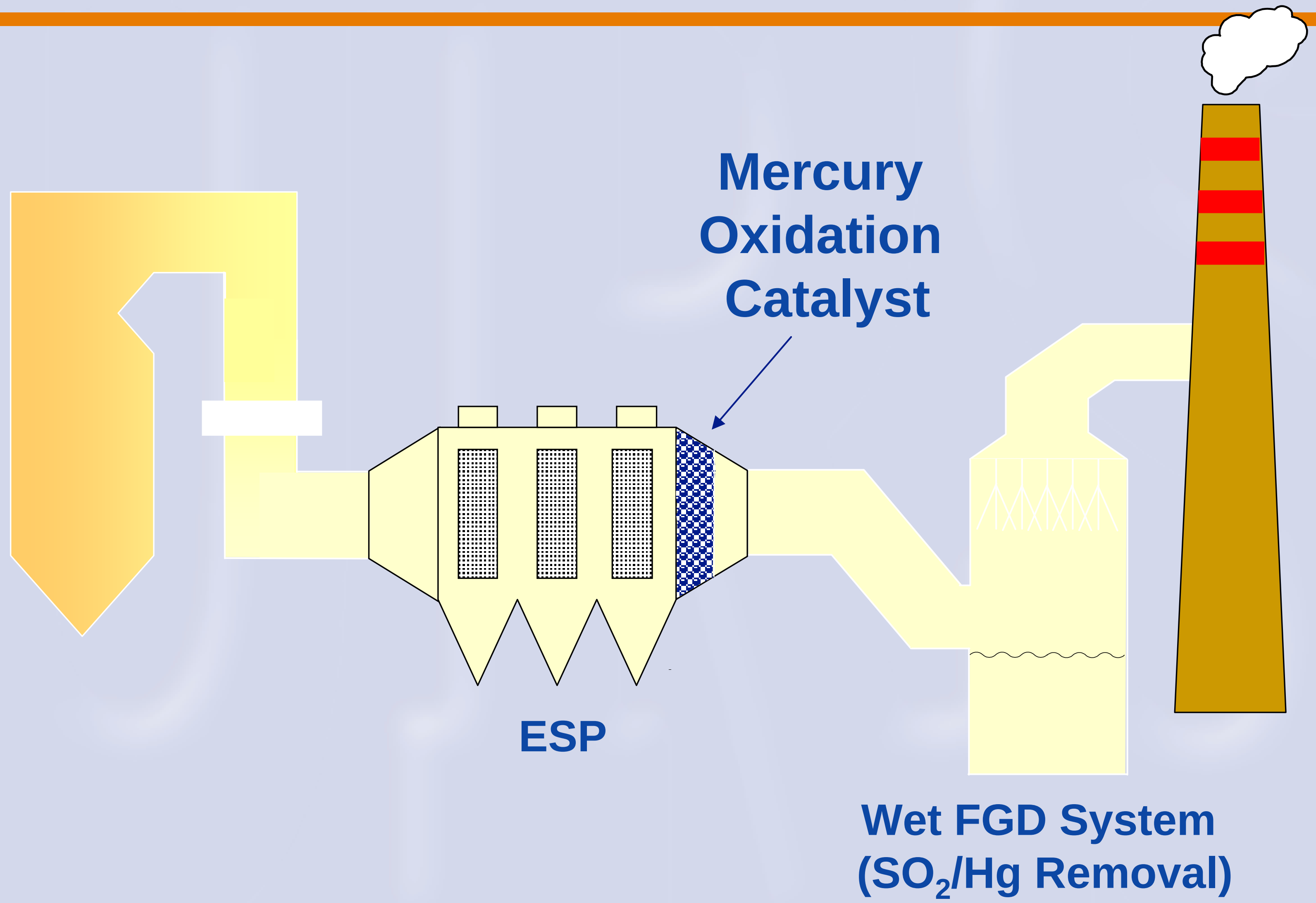
URS Corporation

Austin, TX

NETL COR: Bruce Lani

EPRI PM: Richard Rhudy

Illustration of Process Concept



Project Background

- Two projects conducting pilot-scale tests of honeycomb Hg^0 oxidation catalysts, two sites each
  - 4 catalysts tested in parallel (~2000 acfm each)
  - 14+ months automated operation at each site
  - ~Bimonthly catalyst activity measurements
- Testing fuel/plant configurations that produce higher Hg^0 percentages in flue gas
  - ND lignite and PRB in first project
  - TX lignite/PRB and LSEB fuels in second

41185 Project Pilot Testing

- **GRE’s Coal Creek (ND lignite, ESP/wet FGD)**
  - Pilot unit started up October 02 (2 of 4 catalysts)
  - Long-term test completed June 04
  - Catalyst regeneration tests July, September 04
- **CPS’ Spruce (PRB, FF/wet FGD)**
  - First 2 catalysts started up August 03
  - Long-term test completed April 05
  - Catalyst regeneration tests April/May 05

41992 Project

- TXU's Monticello Station (TX lignite/PRB, ESP, LSFO wet FGD)
  - began January 05
- Southern Company's Plant Yates (low S Eastern bit., ESP, CT-121 wet FGD)
  - to begin August 05
- Build and operate new wet FGD pilot unit downstream of oxidation catalysts
  - 2000 acfm inlet flow rate to match one catalyst
  - Conduct short-term wet FGD tests at all 4 sites
  - Can test LSFO vs. Mg-lime chemistries

Catalyst Types Tested

- Metal-based
  - Palladium (Pd #1) – All sites
  - Ti/V (SCR) – Coal Creek, Spruce, Monticello
    - Cost shared by Argillon, MHI/Cormetech
  - Gold (Au) – Spruce, Monticello, Yates
    - Cost shared by TVA
- Carbon-based
  - Experimental activated carbon (C #6) – Coal Creek, Spruce
- Fly-ash-based – Coal Creek only

Hg Oxidation Catalyst Pilot Unit at Coal Creek Station (CCS)

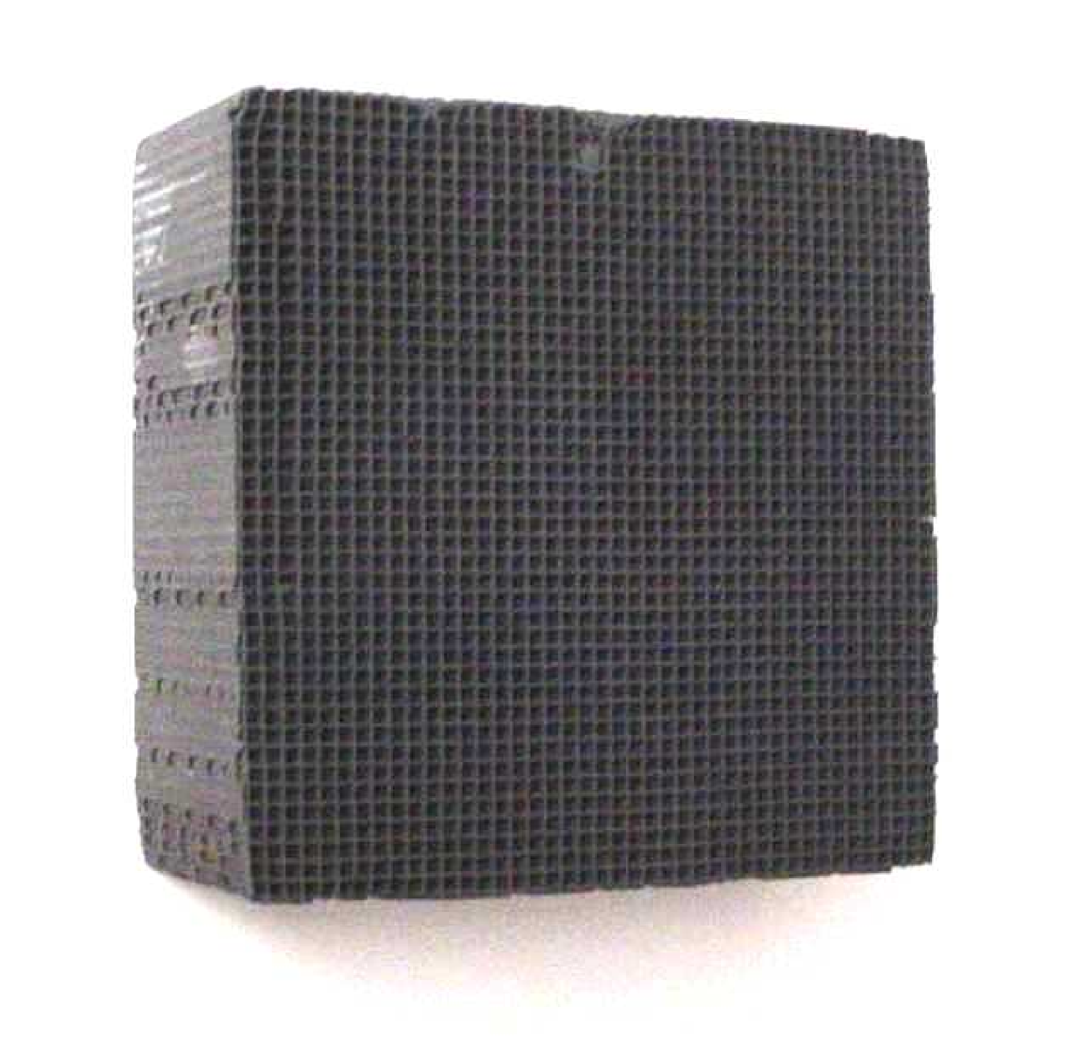
Catalyst Dimensions for CCS Pilot

Catalyst	Cells per in.^{2} (cpsi)	Cross Section (in. x in.)	Length (in.)	Area Velocity (sft/hr)
Pd #1	64	30 x 30	9	49
C #6	80*	36 x 36	9	27
SBA #5	80*	36 x 36	9	27
SCR	46	35.4 x 35.4	19.7	14**

*Die sized for 64 cpsi, cores shrank during drying

**1500 acfm, other catalysts operate at 2000 acfm

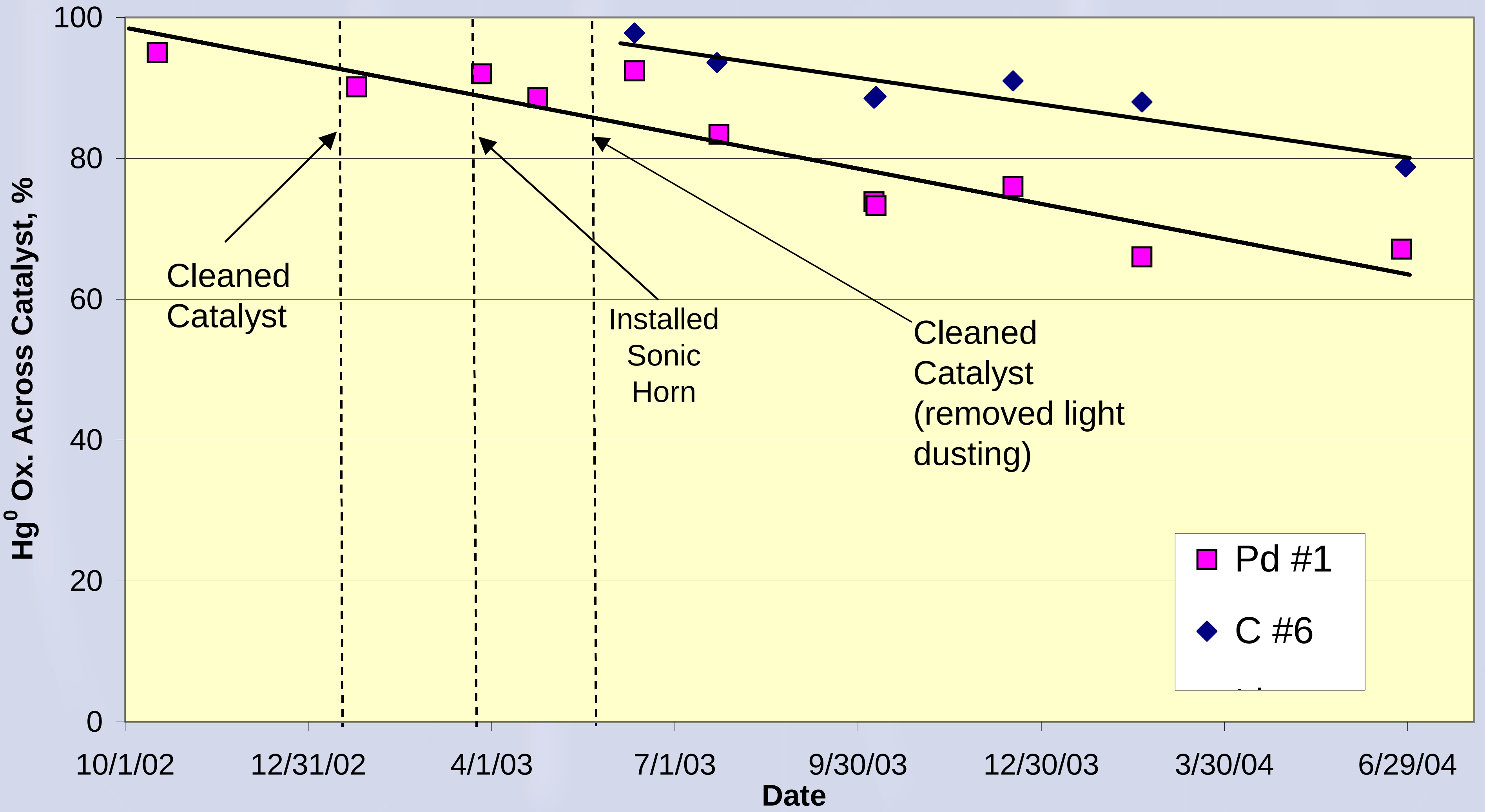
Close-up of One Catalyst Block



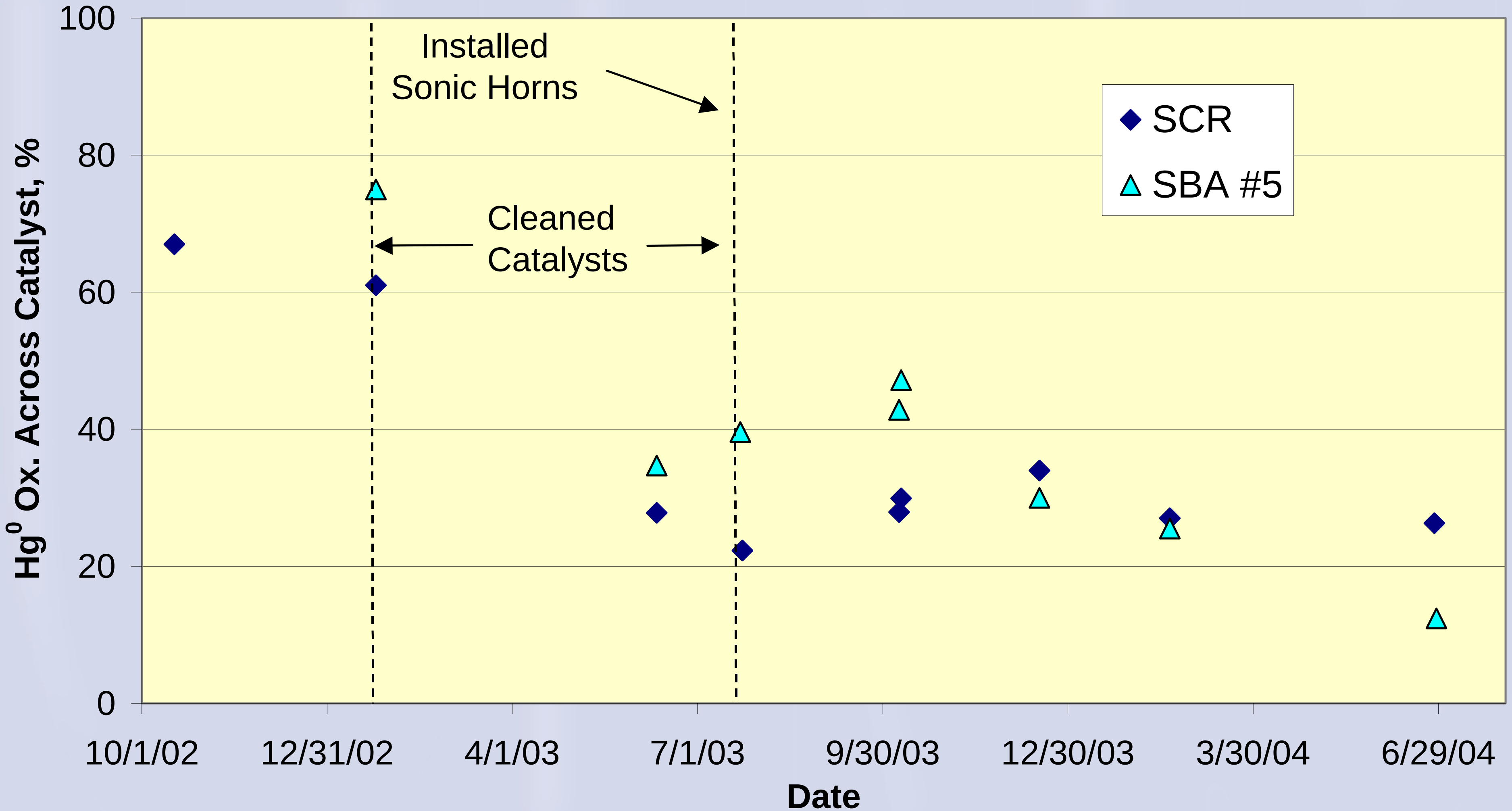
Example Catalyst Installation

Sonic Horn Installation on Pilot Unit

Catalyst Activity Trends over 20 Months at Coal Creek



Catalyst Activity Trends over 20 Months at Coal Creek



Coal Creek In Situ Catalyst Regeneration Tests

- Closed flue gas inlet to catalyst chamber, drew air through 36 kW heater, heated to 600^{o}F
- Ran each regeneration overnight (280 acfm air rate, max. catalyst chamber outlet temperature 410-420^{o}F)

Catalyst Regeneration Test Results

- Pd and SCR catalysts showed improved Hg^0 oxidation activity, C #6 did not
- Results considered "proof of concept" only
  - Temperature, duration not optimized
  - Regeneration limited by heater size, and temperature limit of downstream control valves (450^{o}F)
  - Not sure how uniformly heated air was distributed across catalyst face
  - Did not open compartments to clean any catalyst surface area covered with fly ash (i.e., not regenerable)

Coal Creek Catalyst Regeneration Test Results

	Catalyst Activity, % Oxidation of Hg^0			
Catalyst Type	**Fresh Catalyst**	**End of Test (6/04)**	**Prior to Regeneration**	**After Regeneration**
Pd #1	95 (10/02)	67	79 (7/04)	88 (7/04)
SCR	67 (10/02)	26	25 (7/04)	46 (7/04)
C #6	98 (6/03)	79	~53 (9/04)	48 (9/04)

FGD Pilot Unit at Coal Creek

Coal Creek Wet FGD Pilot Results – Pd #1 Catalyst, LSFO Chemistry

	Total Hg	Hg^0	Hg^{+2}
Catalyst Inlet (µg/Nm^3)	18.0	11.9	6.1
FGD Inlet (µg/Nm^3)	17.4	2.71	14.7
FGD Outlet (µg/Nm^3)[lb/Tbtu]	3.73 [2.5]	3.76	-0.03
FGD Hg Removal (%)	79	-39	100

Cost Estimates – Catalytic Oxidation vs. Conventional ACI

- ND lignite flue gas
  - ACI performance based on Stanton Unit 1 data
  - Catalyst results based on Coal Creek pilot
- Assumed increase of 55% Hg capture compared to baseline removal
  - Minimum removal for oxidation catalyst case
  - Average removal for ACI
- Assumed 2-yr catalyst life
  - Sensitivity case considered 1 regeneration after 2 yrs

Cost Estimate Results – Catalytic Oxidation vs. Conventional ACI

- Best case for oxidation catalyst – plant with existing wet FGD that sells fly ash
  - Catalytic oxidation cost ~60% of ACI cost for 2-yr catalyst life
  - Little difference in cost between Pd and C #6
  - 1 regeneration cycle (Pd) lowers estimate to ~40% of ACI cost
- If plant does not sell ash – ACI and oxidation catalyst costs ~ equal for 2-yr catalyst life
  - 1 regeneration cycle lowered estimate to 60-70% of ACI

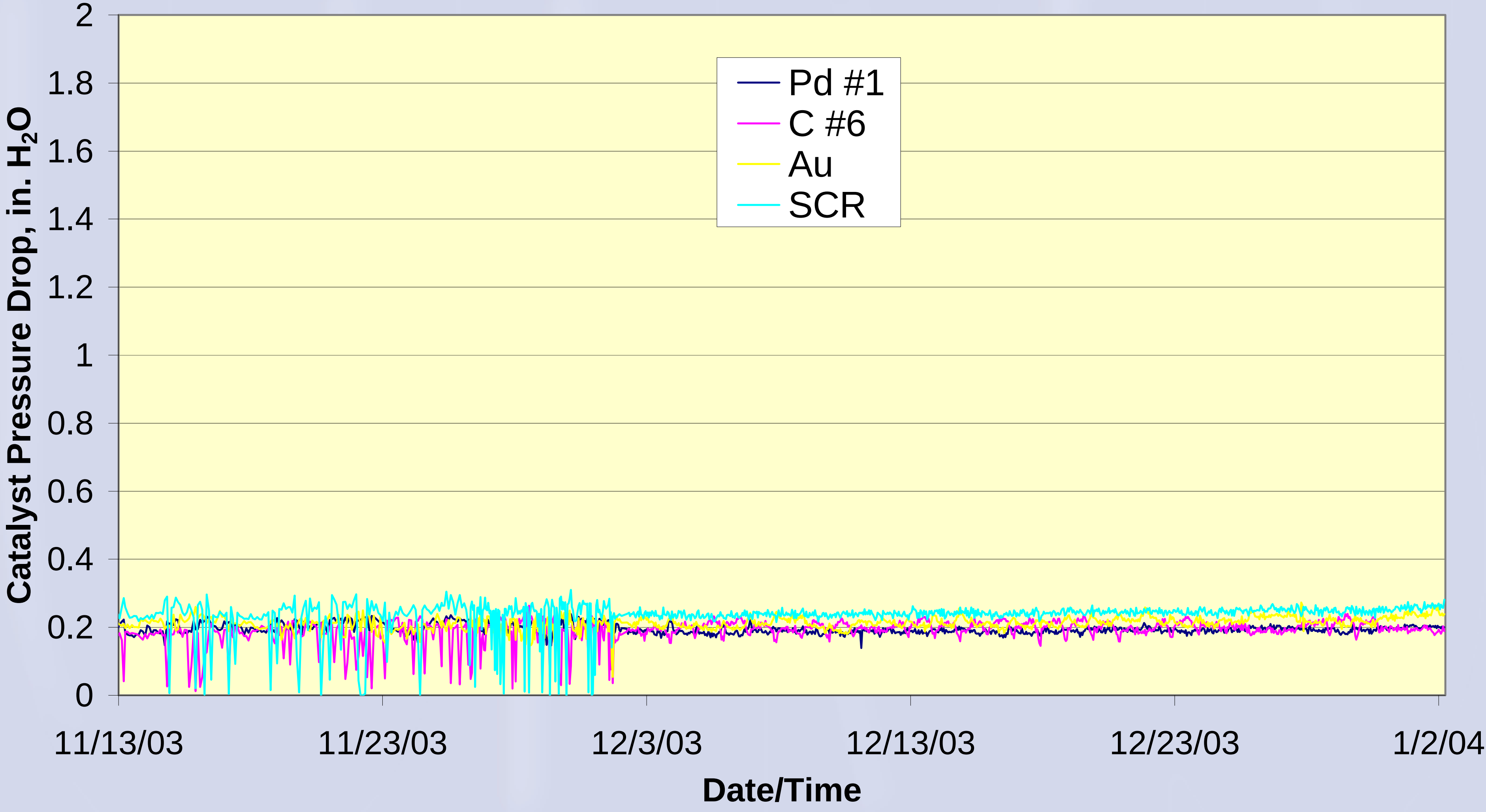
Second Pilot Unit at Spruce Plant

Catalyst Dimensions for Spruce Pilot

Catalyst	Cells per in.^{2} (cpsi)	Cross Section (in. x in.)	Length (in.)	Area Velocity (sft/hr)
Pd #1	64	30 x 30	9	49
Au	64	30 x 30	9	49
C #6	80*	36 x 36	9	27
SCR	46	35.4 x 35.4	29.5	13

*Die sized for 64 cpsi, cores shrink during drying

Catalyst Pressure Drop since 11/13 (no sonic horns in compartments)

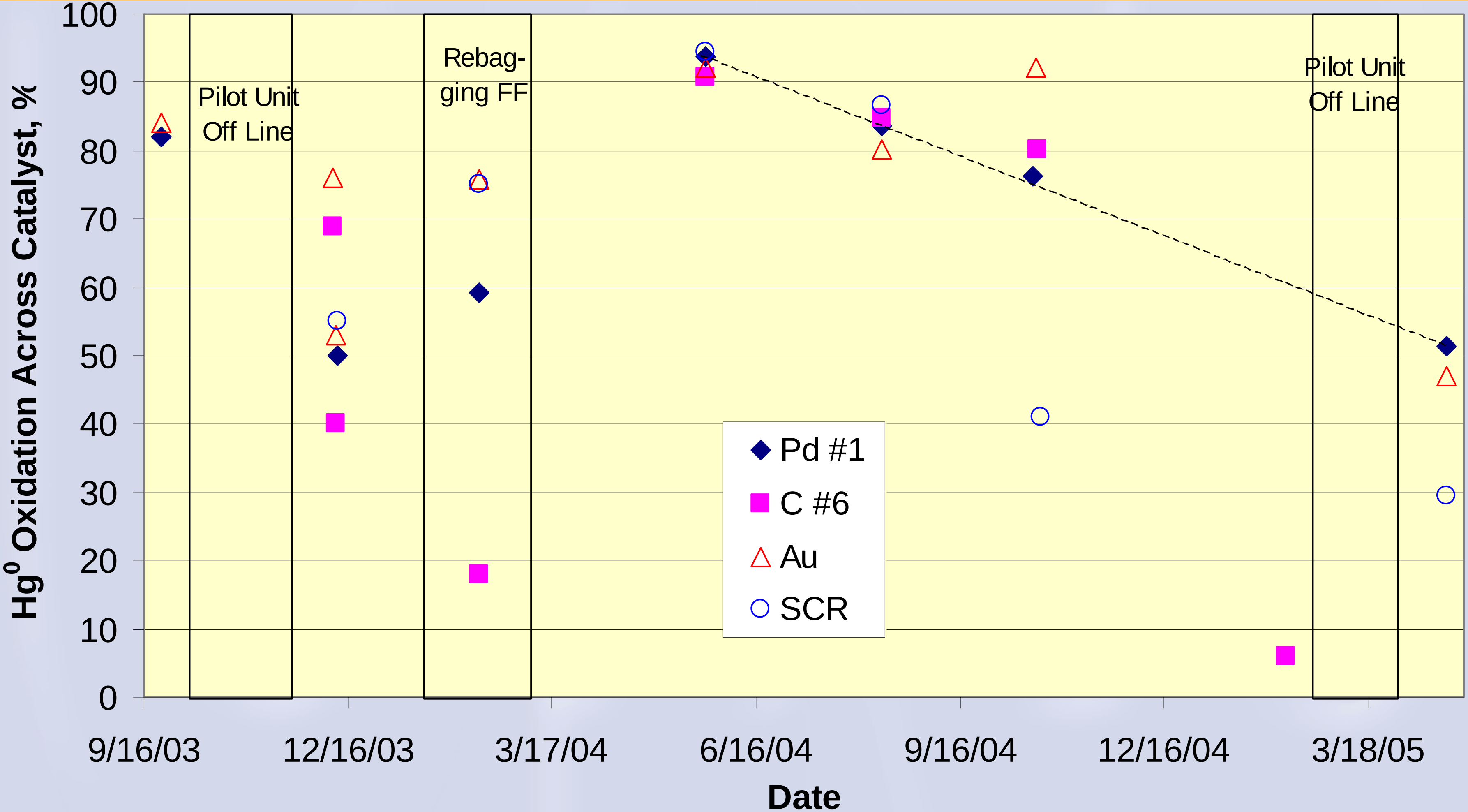


Spruce End-of-Test Activity Results (April 2005)

Catalyst	Catalyst Inlet Hg^0 ($\mu g/Nm^3$ @ 3% O_2)	Catalyst Outlet Hg^0 ($\mu g/Nm^3$ @3% O_2)	Hg^0 Oxidation Across Catalyst (%)
Pd #1	1.32	0.64	51
C #6	1.26*	1.18*	6*
Au	1.48	0.78	47
SCR	0.80	0.56	29

*February 2005 data

Spruce Catalyst Activity Results



Pd #1 results are the only ones that show a linear loss of activity over the past year

Spruce Catalyst Regeneration Results, April-May 2005

Catalyst	Catalyst Inlet Hg^0 ($\mu g/Nm^3$ @ 3% O_2)	Catalyst Outlet Hg^0 ($\mu g/Nm^3$ @ 3% O_2)	Hg^0 Oxidation Across Catalyst (%)	Pre-Regen. Hg^0 Oxidation (%)
Pd #1	1.17	0.19	84	51
C #6	0.94	0.41	56	6
Au	0.88	0.19	78	47
SCR	0.90	0.30	66	29

FGD Pilot Unit at Spruce Plant

Spruce Wet FGD Pilot Results – Baseline – No Catalyst

	Total Hg	Hg^0	Hg^{+2}
FGD Inlet ($\mu g/Nm^3$)	8.5	0.6	7.9
FGD Outlet ($\mu g/Nm^3$)[lb/Tbtu]	5.3 [3.4]	3.8	1.5
FGD Hg Removal (%)	38	-500	81

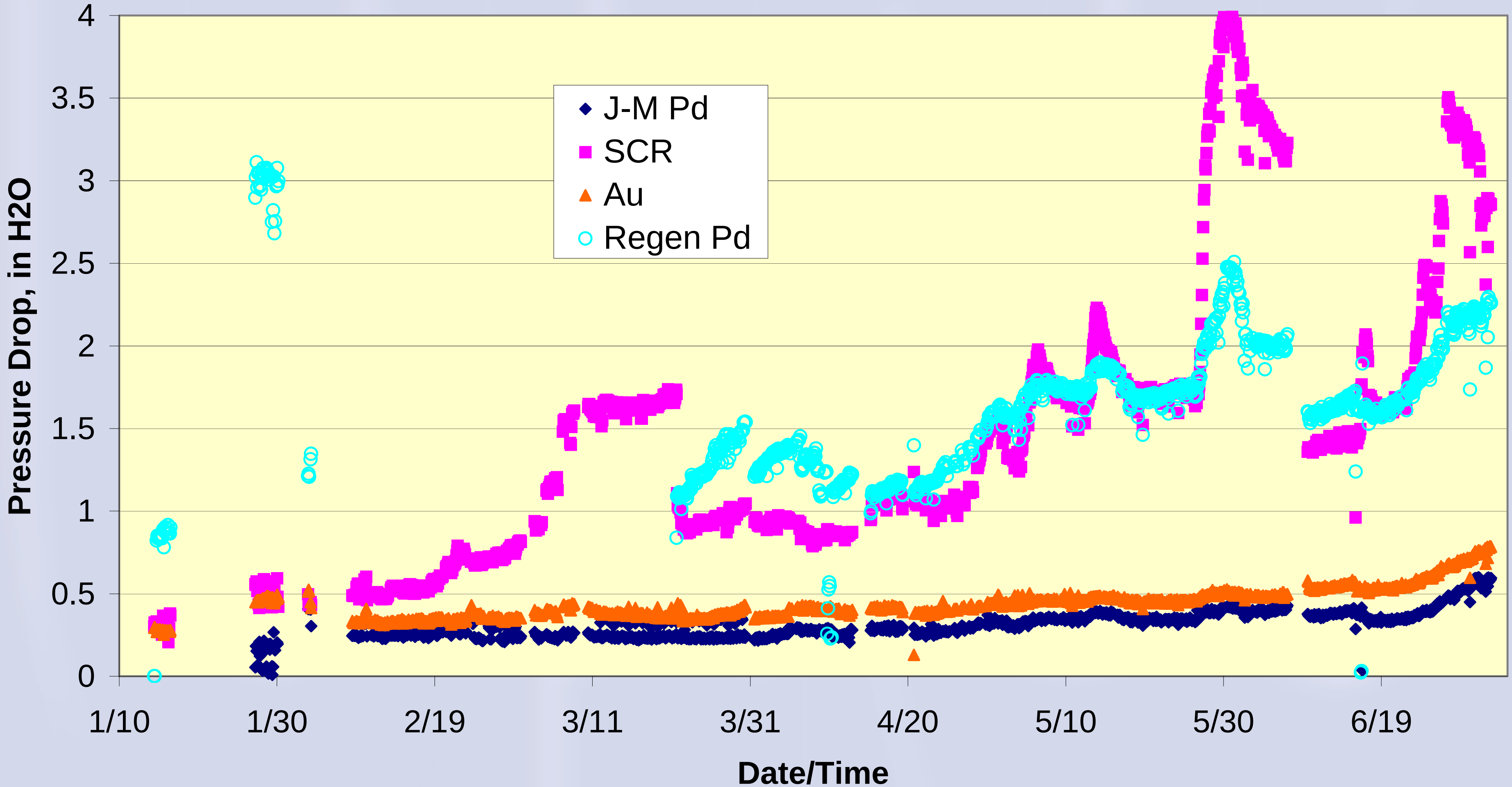
Spruce Wet FGD Pilot Results – Au Catalyst, LSFO Chemistry

	Total Hg	**Hg^0**	**Hg^{+2}**
Catalyst Inlet ($\mu g/Nm^3$)	8.9	2.7	6.2
FGD Inlet ($\mu g/Nm^3$)	10.9	1.0	10.0
FGD Outlet ($\mu g/Nm^3$)[lb/Tbtu]	2.5 [1.6]	2.1	0.4
FGD Hg Removal (%)	77	-116	96

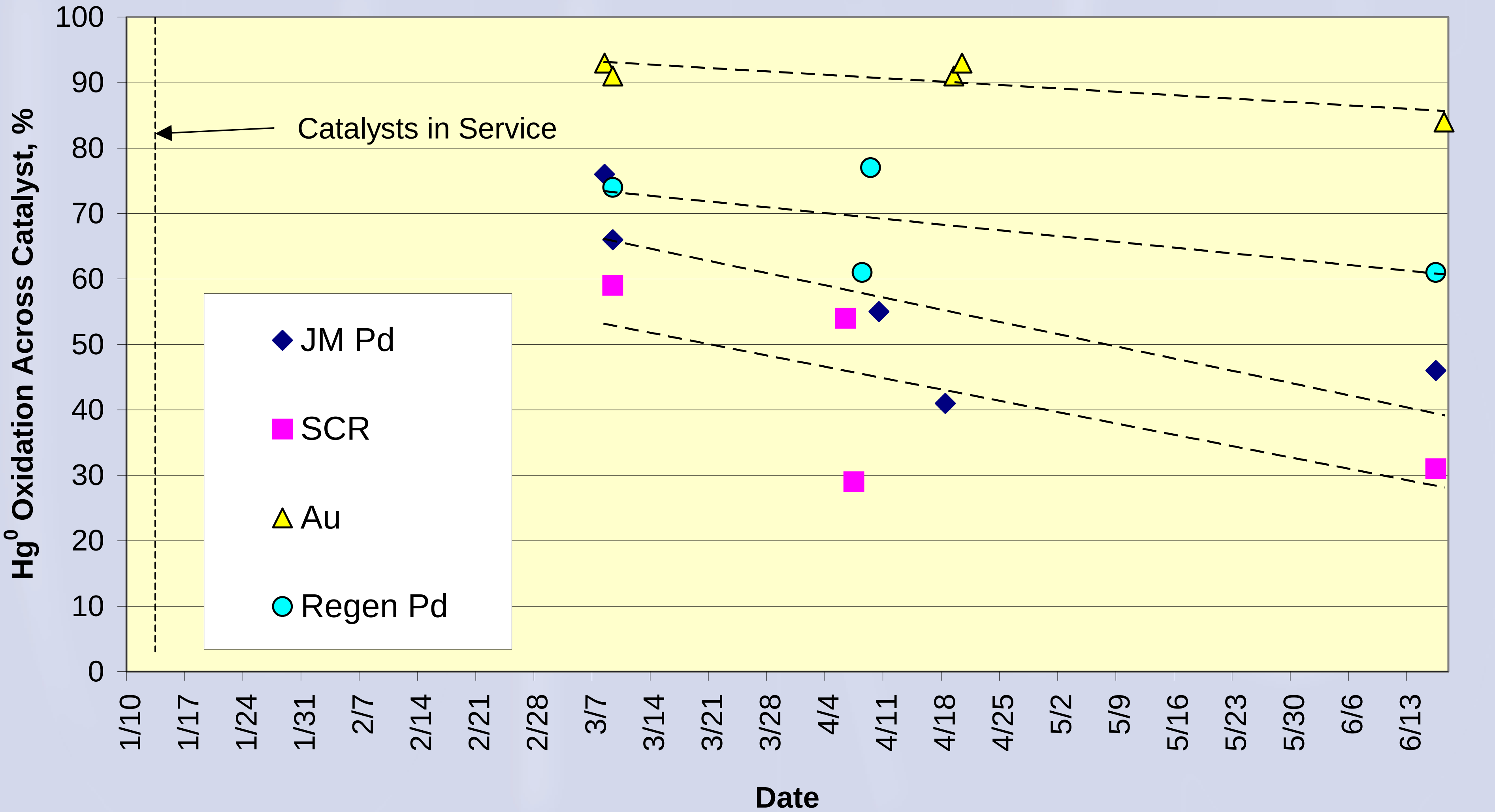
41992 Project – Monticello Pilot Catalysts

Catalyst	Cross Section, in x in	Catalyst Depth	Cell Pitch, mm	Cells per Sq. In.	Area Velocity, std. ft/hr
Gold (Sud-Chemie Prototech)	29.5 x 29.5	3 x 3 in.	3.2	64	52
Pd #1 (Johnson Matthey)	29.5 x 29.5	9 in.	3.2	64	52
Pd #1 (regenerated from CCS)	29.5 x 29.5	3 x 3 in.	3.2	64	52
SCR (Cormetech/MHI)	35.4 x 36.2	29.5 in.	3.3	58	12

Monticello Catalyst Pressure Drop Data



Monticello Catalyst Activity Data



Pilot Wet FGD at Monticello

Pilot Wet FGD Data by SCEM

Catalyst	Catalyst Out/FGD Inlet Hg, μg/Nm^3 @ 3% O_2		FGD Outlet Hg, μg/Nm^3 @ 3% O_2		Total Hg Removal by FGD, %	Hg^{+2} Removal by FGD, %	Hg^0 Removal by FGD, %
	Total Hg	Hg^0	Total Hg	Hg^0			
None	22.4	13.9	12.1	9.9	46	74	29
SCR	23.1	11.0	6.4	4.5	72	85	59
Regen. Pd	31.6	5.0	8.6	3.4	73	81	31
J-M Pd	28.8	7.9	4.6	2.4	84	89	70
Gold	31.7	1.5	7.7	2.1	76	81	-43

Flue Gas Characterization Results

- Ontario Hydro results do not always agree with Hg SCEM results
  - Inlet values agree reasonably well
  - OH often shows lower Hg^0 concentrations at catalyst outlets than Hg SCEM
    - Bias most apparent for SCR catalyst, JM Pd
  - Reason for bias remains unclear
    - Possible formation of alternate oxidized Hg form across catalysts?

Conclusions

- Sonic horns are required to keep horizontal gas flow catalysts clean downstream of ESPs
- Hg oxidized by catalysts removed by wet FGD at high efficiency, can be limited by re-emissions
- Catalysts can remain active up to 2 yrs
- Economics show possible lower cost than ACI
  - Economics best for plants with FGD that sell ash
  - Catalyst regeneration greatly improves economics
    - New EPRI project will optimize regeneration conditions
  - Low-cost carbon raw material catalyst no less expensive than precious metal catalysts